DECISION LOOPS: THE CYBERNETIC DIMENSION OF BATTLE COMMAND

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Abstract

Modern communications, data processing systems, and the complexity of modern land warfare have led to the explosion of information in tactical combat organizations. The commander must use this information within a decision process to exploit its value. This monograph examines how the rational and cybernetic decision processes are used in tactical battle command. It explores the decision loop, a cybernetic decision process based on feedback, as a means to connect information directly to action and exploit the time value of information.

The rational decision process, the analytical process of choosing an optimum course among alternatives, does not support the rapid use of information. The cybernetic decision model, the use of feedback to regulate action, provides an alternate means of exploiting the time value of information. This model views command as a control problem with the objective of controlling both the enemy and friendly forces on the battlefield. In order to control the battlefield, the variety (a function of the number and type of component parts, and possibilities of employment) of the control system must match the system being controlled.

The criteria of fast-acting, self-regulating, and self-organizing are applied to analyze the Boyd cycle or observe-orient-decide-act (OODA) loop, the recognition-primed decision (RPD) model, and the Lawson loop. The OODA and RPD loops do not provide the framework for self-regulation or self-organization. The Lawson model differs by providing a regulator that compares feedback to a desired state. This suggests two layers of decision: an execution layer that translates information to action, and a

planning layer to design and adapt the regulator. This two layer system, when networked to higher and sister echelons, provides the basis of a self-organizing system that acts around the authority of information. Specifically, collective action builds around predetermined decision rules. Decision loops can then exploit the time value of information.

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I. Introduction

Austerlitz (December 2, 1805). On the morning of the battle, about eight o'clock, Napoleon observed the Russian columns moving south along the Pratzen Heights. He received word that the combined forces of Austrians and Russians had captured the villages of Telnitz and Zokolnitz about two miles to his south pushing back Davout's III Corps on the French right flank. Napoleon consulted with the IV Corps commander, Marshall Soult, to find that the counterattacking divisions could be on the heights in twenty minutes.[1] The Emperor had conceived his plan and placed himself at the critical point on the battlefield. His plan required careful timing. He had to unleash the counterattack when the allied center diminished to its weakest level, without allowing the defeat of his right flank. He could observe enemy regiments shifting south from the center, receive reports of the battle on his right flank, and consult with the commander of the counterattack force. The outcome of the battle gave Napoleon his greatest military victory.

Austerlitz, in many ways, represents a commander's ideal battle: seeing the battle unfold before your eyes as you imagined it, then commit the counterattack force at the critical moment with a nod to its commander. However, few army commanders since Napoleon have achieved the degree of battlefield awareness that allows such a performance. The Austerlitz battlefield was no more than 6 miles wide and 9 miles deep, yet 160,000 soldiers fought there.[2] The lethality of modern weapons forced soldiers to disperse at a faster rate than the pace of lethality itself:

> In ancient times, one man probably occupied 10 square meters of battlefield, and this increased little until the nineteenth century. In the American Civil War one man occupied rather over 200 square meters; in

> World War One, over 2,000 and in World War Two, over 20,000. Dispersion has in fact increased more than lethality, and this explains why, for example, casualty rates in combat were lower in World War Two than in World War One or the American Civil War.[3]

Inventions such as breech loading rifles (allowing reloading in the prone), smokeless powder, entrenched fighting positions, and camouflage have all but emptied the battlefield.[4] The modern commander sees few of his soldiers and even less of the enemy at any one time.

The modern tactical commander must cope with much more variety[5] than Napoleon. A dispersed formation inherently creates greater freedom of action for subordinate units. Having more types of combat systems demands special attention for proper coordinated employment. Mechanization, especially the employment of armored and aviation forces, increases the tempo and decreases the time that decisive force can be brought to bear on a single point. It elevates logistics from strictly a march consideration to a dynamic factor in the battle. It started the explosion of new systems and countersystems such as the tank and the anti-tank guided missile. In essence, mechanization began the explosion of variety for the commander. Besides creating more work, variety has increased the commander's uncertainty. Variety and uncertainty are related concepts. However, variety dominates the commander's command and control problem. Since Napoleon had less of it, he personally managed it with the help of an inner circle of aides. The modern commander, even a genius, does not have this option. He or she must seek another solution.

The material economy has undergone a similar explosion in variety. The increasing complexity of the commercial system precipitated a "crisis of control:"

> Suddenly, in a manner of decades, goods began to move faster than even

> the winds themselves, reliably and in mounting volume, through factories, across continents, and around the world. For the first time in history, by the mid-nineteenth century the social processing of material flows threatened to exceed in both volume and speed the system's capacity to contain them. Thus was born the crisis of control . . .[6]

The growth of formal bureaucracy became "Foremost among all the technological solutions to the crisis of control . . ."[7] The military staff took a similar course with the growth of larger armies. Indeed, by the end of the nineteenth century most major armies had adopted a general staff system that mirrored the emergent state bureaucracies.[8]

Today, increasing variety coupled with high information flow creates the impression of paralysis. Contemporary military historians and analysts argue that the staff itself has become an impediment to command. Martin van Creveld, in his landmark work <u>Command in War</u>, contends that the system developed to handle information, the growth of the staff, paradoxically reduces its value in the decision making process:

> To cope with the flood of information, staff was piled upon staff, procedure upon procedure, machine upon machine. With each stage in the growth of staffs, the problem of coordinating the staff's parts with each other, and the staff as a whole with the forces, was compounded. With each new well-defined procedure or formal language, the gain in reliability and precision was offset by the decline in information communications, redundancy, and flexibility that are indispensable for the generation of ideas.[9]

Indeed, large staffs can take on a life of their own. J. F. C. Fuller compares the staff bureaucracy to a "paper octopus squirting ink and wriggling its tentacles into every corner."[10] Daniel P. Bolger echoes this sentiment in his article "Command or Control?" by complaining that each staff officer "contributes his glassful to the ocean of information bilge that soon drowns the unwary commander in his own doubts."[11] The solution appears to have become the problem. The systems established to handle variety and information appear to have resulted in removing the commander from the business of influencing the battle. Battle command may have entered a new crisis of control.

What can be done? Modern technology promises greater situational awareness together with artificial intelligence based decision aids. The U.S. Army's concept of *Army Battle Command System* (ABCS) promises to integrate friendly and enemy situations into digitized images graphically represented in heads-up displays at all levels of command.[12] Commanders will share the *common relevant picture* of the battlefield in their coup d'oeil goggles.[13] But, can these information age technologies free the commander from the shackles of his staff and allow a modern day Napoleon? Will this technology empower small units and individuals for independent action?[14] Conversely, will it tempt the commander into controlling a level of variety and uncertainty that cannot possibly be managed? Rather than attempting to answer these questions directly, this paper will explore how information can be best applied to the decision process. More specifically, this paper will explore how efficient *decision loops* can effectively exploit high volumes of information to achieve effective control and battlefield success.

Decision loops are an outgrowth of a cybernetic view of management and decision. Decision is based on comparison of *feedback* to a desired end-state. Understanding the cybernetic process is best done by comparing it to the rational decision-making process. A rational decision thesis "holds that a man acts to maximize his values under the constraints he faces."[15] The process involves the optimal choice between all possible alternatives. The rational decision process requires two conditions: perfect information or the ability to quantify the uncertainty as a probability, and a method to weigh the values of the outcome. This process uses analytic tools such as decision trees, decision matrices, and other direct calculation techniques.

Cybernetic decisions follow a different process. The focus of this process ". . . is eliminating the variety in any significant decision problem."[16] Cybernetics consists of a series of decisions in time based on feedback - the continual monitoring of the state of the system. Decision loops characterize the cybernetic process. In general, the process begins with a gathering of information on the military environment (friendly, enemy, terrain, and weather), followed by a comparison with a desired end-state, a decision, and then action. The information gathering process (feedback) continues and drives the cycle until the unit achieves the desired end-state. The decision loop ties information to action.

This paper will examine how the rational and cybernetic decision processes are used in tactical battle command. Specifically it will endeavor to determine if decision loops provide a better method to exploit the time value of information. It will also determine if decision loops better process the full potential of information.

II. THE RATIONAL DECISION PROCESS

The rational decision process attempts to find the optimal solution of a problem by analyzing alternative solutions. This process formalizes the decision process by documenting the considered alternatives, analyzing them in detail, and clearly stating the reasons for selection. The selection is usually based on best value achieved by some form of cost-benefit analysis. This is a formal and quantitative process which employs techniques such as decision trees, linear programming, and net present value. In a tactical setting, the *military decision making process* (MDMP) provides an excellent example. FM 101-5, Staff Organizations and Operations - Draft (August 1996), describes this process as a sequence: receive the mission, analyze the mission, develop courses of action, compare courses of action, and approve (select) the course of action.[17] Receipt of the mission drives the process. On mission receipt, the staff gathers information, analyzes the mission, and develops and compares the alternative courses of action. They then employ war gaming techniques to analyze the alternatives and compare those alternatives using some formal system such as a decision matrix.

While the rational decision is often advanced as the normative model, it has sufficient shortcomings which prevent full implementation except to the simplest of problems.[18] In its purest form, the rational decision process assumes complete information and has an objective and independent means of establishing a best value criteria. This situation, however, is seldom achieved. Assumptions fill information gaps. This often assumes problems away. To prevent this, assumptions are often worded as worst cases that unnecessarily constrain the solution. Uncertainty often creates information gaps. The decision maker can proceed with analytical techniques by estimating the probabilities of the alternate outcomes as one could do for a gambling game. Complex problems, however, are seldom this simple:

> Few real decisions, however, are so nicely structured in this regard as the gambling game, and there are severe conceptual difficulties in assigning probabilities of occurrence to events for which neither of these procedures [the other being direct measurement of the probabilities] is applicable. Many critical events affecting complex policy problems occur only once, and many events which decision makers worry about never occur at all.[19]

For instance, a weather prediction usually includes a probability. This prediction was formulated from models, which use measurements as the input and base calculations on physical laws. A numerical probability cannot be as easily assigned when analyzing possible enemy courses of action. While analysis of doctrine may qualify a likely or unlikely course, the fact that the enemy is a positive thinking opponent limits usefulness of this numerical treatment.

In the rational paradigm, decision makers compare alternatives to pick some form of best value. When the decision involves the comparison of two or more separate values the decision maker must assign a utility or weight to each of these values. Since an independent and objective basis for assigning the weight is seldom available, the decision maker must rely on discretion to arrive at the weights. This in itself is not bad unless the decision must be completely objective, which is not the case in most tactical situations. It does mandate a subjective trade-off consideration when comparing the two values. This process, unfortunately, gives the illusion of a complete trade-off analysis when all possible trade-offs cannot reasonably be considered.[20] A decision matrix complete with weights and values gives an illusion of objectivity to the decision, but, in fact, the weights assigned and the trade-offs considered are subjective.

Complexity is another element that acts as a barrier to a complete rational decision process. Complexity develops from even simple sets of rules played in combinations. The total set of feasible alternatives can rapidly exceed any possibility of detailed analysis. For instance, in chess there are only six different types of pieces giving six basic rules for movement, and a total of thirty-two pieces operating on sixty-four spaces. Chess is a zero-sum game: during each move a player has a finite choice of moves, and one player's gain is the opponent's loss. Zero-sum games have optimal solutions. However, in reality the optimal solution is intractable.[21] Tactical combat, easily more complex than chess, will not have an optimal plan that can be found. Problems with near infinite possible solutions and incomplete information mandate another approach.

In 1947, Herbert Simon developed the concept of *bounded rationality*. In essence, his thesis acknowledged that humans are bounded by their information processing capability. Humans can only weigh a limited set of alternatives and usually with incomplete information. Decisions, therefore, are based on heuristics or organizational rules-of-thumb.[22] The military decision making process works within the concept of bounded rationality. To simplify the alternatives and deal with uncertainty the military organization bases its heuristics of decision in doctrine and standing operating procedures.

The military staff supports the bounded rational decision process: by processing information and developing alternatives for the commander's decision. Like a bureaucracy, the staff is an excellent information processing machine. It sorts, distributes, compartmentalizes, and analyzes tremendous amounts of information to give the commander the tools he or she needs to make a decision or issue guidance. Information enters the process via three modes identified in a RAND study of *War Fighter Exercises* (WFX). Choice of these modes; the pipeline, the alarm, and the tree; depends on the nature and urgency of the information. The pipeline handles routine reports between the staffs of lower and higher headquarters. The alarm responds to an exceptional event that is either predetermined in the *commander's critical information requirements* (CCIR), or conflicts with how the commander expects the battle to unfold. The tree is a systematic search to answer an informational need of the commander not handled by the pipeline or alarm.[23] These information routes reveal the isomorphic nature of staffs between different echelons; like staff sections communicate in pipelines. It also reveals the branching of the general to the specific within the staff; coordinating staff officers have large subordinate structures that can function virtually isolated from other staff sections. A tree search finds information by moving down the branches of increasing specialty. The appliqué of information technology on to the staff system increases the efficiency of the three modes, but it does not necessarily change the decision process.

Technology can serve as a detriment to the rational decision process. It increases the number and costs of potential alternatives. It increases the numbers and types of systems available to the commander. The range and speed of the friendly systems create dynamic problems of employment; the potential for conflict between friendly systems is enormous. Finally, technology moves this explosion of information rapidly to the decision maker.

> Automation is seen to exacerbate this problem by producing a kind of 'information explosion.' Technological advances in sensor systems, for

> example, are said to have developed to a point at which a commander can be inundated with incoming facts and statistics. Systems such as the Maneuver Control System (MCS) can produce over 100 automated reports to division and corps, some of which contain information that is critical for the force-level commander. The problem lies in identifying what subset of information is critical.[24]

How will the human decision maker cope with this? The case of the USS *Vincennes* highlights the problem. Once the Iranian airbus appeared on the cruiser's radar screen the commander had minutes to make a rapid decision while dealing with a flood of information. Kenneth C. Allard discussed the issues that the commander had to address:

> . . . even such a sophisticated system could not offset the effects on the crew of time compression (three minutes and forty seconds from the time of first sighting until the instant the captain had to make the decision to launch missiles), confusion, fear (the ship had just repelled an attack by Iranian gunboats), and even the ghost of the USS *Stark* tragedy a year before. . . . This aspect of the Iranian airbus tragedy highlights the third basic concern of naval command and control: increasing the ability of naval commanders and their staffs to deal with a data stream that is rapidly becoming a torrent.[25]

Future commanders will face similar situations by making split second decisions of immense consequence while trying to absorb an incredible amount of sometimes contradictory information. Yet the decision methods and basic organizational structure of the staff have not significantly changed for decades. This structure is culturally embedded.

Sociological forces as well as utility shapes the structure of the staff. Stafford Beer calls one sociological force *Homo Farber* or man the builder. He argues that man holds value in the building of things. When information becomes a "thing," man collects it, develops it, and creates information products such as staff estimates. Information becomes an item of value to control and protect. Beer's next sociological force is man's view of organization. This he terms *Totem Quantum*: the component parts, the quanta, are linked by a well defined chain-of-command – the totem. Man creates these organizations by dividing and subdividing down to the quanta supported by clear chains-of-command. Beer claims that this model is our organizational stereotype.[26] Problems arise in this stereotype when one branch of the tree needs to work with another branch. Beer writes:

> It becomes essential that a decision made by one quantum at a particular level in the organizational hierarchy should carry its cousin quanta with it. But the organizational stereotype does not offer a lateral means of communication. Therefore we must do the best we can. We set up committees, working parties, interdisciplinary studies, international commissions, inter-departmental liaison groups, cross fertilizing mechanisms of every kind . . . . But the fact remains that the organizational stereotype does not acknowledge these things, with the result that no one knows where authority lies.[27]

As long as we adhere to this organizational stereotype, we accept tenuous coordination between branches of the staff. Indeed, the compartmentalization of information leaves synthesis to the chief of staff or even the commander at the evening staff update.[28] This method is far too slow to exploit the time value of information.

While the rational paradigm provides a valid decision framework, it is not well suited to exploit the time value of information. Further, the complexity of modern warfare limits the completeness of this method. Decision makers are bounded by the limits to the information that they can absorb and the alternatives they can consider. In choosing their bounds, they introduce subjectivity into the process. Military staffs are well suited to support this decision process, especially in their garrison environment. However, the structure of these staffs inhibits the exploitation of the time value of information on a highly dynamic battlefield.

Problems will increase in the future. The rapid growth of technology has led to the explosion of information. The Army should adopt better methods to exploit the value of information. New methods must rapidly turn information into action. Cybernetic decsion methods connect information, in the form of feedback, to action.

III. The Cybernetic Decision Model

In 1948 Norbet Weiner published his book. Cybernetics: or Control and Communication in the Animal and the Machine. His title expressed his definition of the new branch he formed – the science of control and communication. The word cybernetics comes from the Greek word for ". . . steersman – a pilot that steers a ship."[29] As a steersman, the commander of a tactical unit guides the unit by communications and control. In cybernetics, the control works through feedback – the communication of information on the state of the system. The commander receives information as feedback and issues orders and guidance to keep the unit on course. This is control. Unfortunately, many people have assigned negative connotations to the word "control." General Foss, a former TRADOC commander wrote, "The proper understanding of control is embodied in the axiom, 'The more control imposed, the less command applied.' Control, by definition, restricts command."[30] He later acknowledges the necessity of control, but insists that it should be held to a minimum. Such sentiment, however, misses the point. Control is not, as in the colloquial definition, always restrictive control. Beniger provides a more general definition:

> Here the word *control* represents its most general definition, purposive influence toward a predetermined goal. Most dictionary definitions imply these same two essential elements: *influence* of one agent over another, meaning that the former causes changes in the behavior of the latter; and *purpose*, in the sense that influence is directed toward some prior goal of the controlling agent.[31]

The commander must exert control to achieve a goal. Ultimately, the commander seeks to establish control of the battlefield both over his forces and against his opponent.

Feedback is the most fundamental aspect of the cybernetic model. Control systems employ feedback to regulate the temperature in a building, level the wings of an aircraft, position the laser pick-up on a CD player, or guide a TOW missile in on its target. Biological systems employ feedback to maintain body temperature, trigger breathing, and regulate the heartbeat. Feedback provides information on the *state* of a system, or the current values of the variables in a system. Two different control systems illustrate the presence and absence of feedback: open-loop control (Figure 1) and closed-loop control (Figure 2).

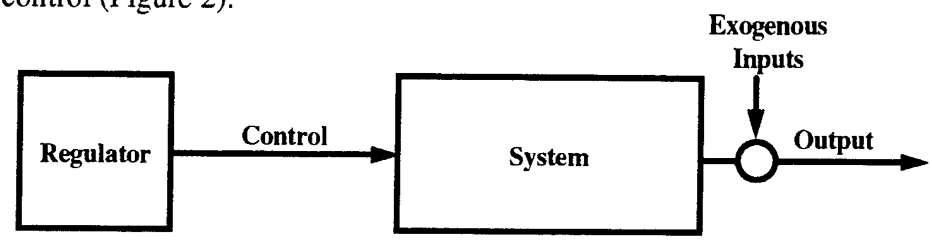

Figure 1. Open-Loop Control

Open-loop control does not use feedback. The regulator determines the solution and exercises control on the system to achieve its goal. The shot of a main battle tank makes an excellent example. The fire control system has an excellent model of the gunnery system. Based on the selected round it determines the muzzle velocity and ballistic characteristics. The laser range finder determines the distance to the target and the anemometer determines the wind direction and velocity. The fire control computes a solution and deflects the gun tube the correct amount from the aim point. Once the tank fires the round, no correction can be made. If exogenous (outside and uncontrollable) variables act, such as an unexpected cross wind or the target moving, or if fire control has an inaccurate model of the ballistics, the round could miss the target. Open-loop control requires an accurate model of the system and a good measure of all variables before acting. A strict rational decision process follows the same paradigm: execution attempts to follow a carefully prepared and detailed plan irrespective of outside influences.

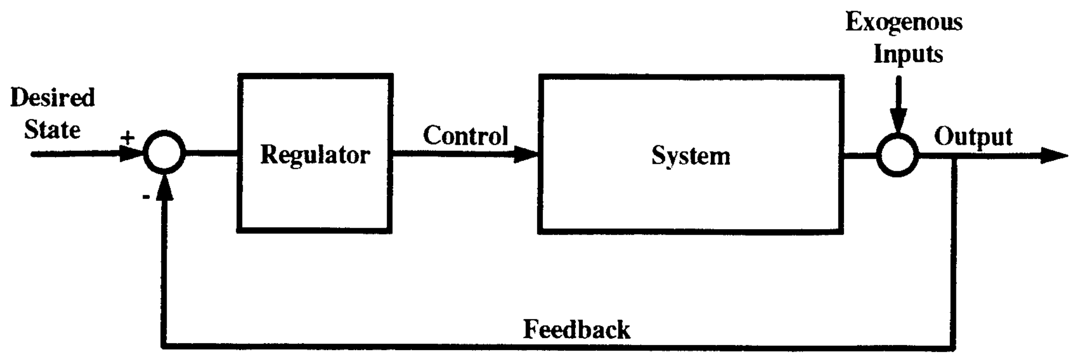

Figure 2 Closed-Loop Control

Closed-loop control employs feedback. It continuously receives information about the state of system and compares it to the desired final state. The regulator applies gain to the error between the system state and desired state to determine the control applied to the system.[32] The modern anti-tank guided missile (ATGM) exemplifies this system. The gunner aims and fires the missile, but continues to track the aim point (desired state). The computer (regulator) automatically determines the error between the aim point and the missile's position (system state) and sends the corrections to the missile. Earlier ATGM systems depended on a human-in-the-loop. The gunner (regulator) observed the missile's position and made corrections by manually operating a control stick. A poorly designed regulator can cause undershoot or overshoot of the desired state. If the overshoot is greater than the original perturbation, the system wildly oscillates toward complete instability. Thus, stable systems require carefully designed regulators. Robust design allows for a wide range of exogenous inputs and an incomplete knowledge of the system being controlled. However, good design only works within limits. If these limits are exceeded the regulator fails. The regulator then must adapt to the new conditions.

W. Ross Ashby focused his work in cybernetics on the modeling of communication and feedback in living systems and applied these concepts to adaptive regulation in mechanical systems. He noticed that living systems not only regulate themselves, they adapt. Ashby uses the example of a kitten placed near a fireplace for the first time. At first, the kitten unfamiliar with fire, behaves erratically. After a short time, the kitten adapts to the presence of the fire, then continually adjusts its position to regulate the distribution of warmth. In his book, Design for a Brain, Ashby develops a theory for what he terms *homeostasis*, a control system capable of adapting. A system regulated with feedback will return to stability if the perturbation does not push the system beyond certain critical values. When the system exceeds these critical values, the homeostat goes through a series of random adaptations until it finds a region that points back toward stability. He refers to the condition achieved by this second adaptive loop as *ultrastability*.[33]

Ashby applies homeostasis to a mechanical example of a wing leveler (a feedback regulator that controls the ailerons to level the wings of an airplane). If you connect the regulator in reverse, the positive feedback would roll the aircraft. However, a homeostat would undergo a series of random adaptations until it achieves a region of stability that levels the wings.

Like Ashby's homeostat, a tactical unit employs a form of adaptive control. The commander uses a good flexible plan as a regulator to make adjustments and keep the unit on schedule toward the objectve (the desired state). If outside stresses move the unit outside critical values the plan no longer works. The unit must go through a series of adaptations to move back in the zone of stability – progress toward the objective. If the commander does not adapt the plan the unit looses stability and fails.

Ashby recognized that the ability to adapt depends on the suddenness of the external stress. For instance, a fish swimming in a tank cannot adapt to the presence of the glass wall if it first detects the wall by contact with its nose. It will collide before it adapts.[34] Here lies the cybernetic advantage of shock. Shock stresses the adversary faster than he adapts, so he looses control of the battlefield.

Control systems such as wing levelers, thermostats, and ATGMs are relatively simple. They measure and control only a few variables. The tactical commander has a much more complex control problem. As stated earlier, the objective is to gain control of the battlefield. What makes this problem difficult is the number of independent moving parts. In these terms, a corps commander's control problem far exceeds that of his counterparts in the air force or navy. General (Ret.) Gorman quantifies the point:

> The Navy vice admiral would logically expect to command 10 to 100 ships, planes, and submarines in a typical carrier battle group at any given time. His Air Force counterpart, a three-star wing commander, however, would have a command and control problem at the next order of magnitude, typically 100 to 1,000 aircraft of all types, in addition to ground reporting and controlling stations. But Marine and Army Corps commanders would have the most complex problem of all: their squads, platoons, companies, battalions, and higher formations typically entail 1,000 to 100,000 *or more* movable subordinate entities.[35]

Moving parts generate variety and uncertainty. While variety and uncertainty relate to each other, this paper will define variety as the more general concept which subsumes uncertainty.

Variety quantifies the possible realizations of a system where uncertainty relates to the lack of information available to the controller or decision maker. A system with a large variety inherently contains a high degree of uncertainty, but removing the uncertainty does not eliminate the variety. For example, consider a single chessman on a chessboard. Without knowledge of its position, the piece may occupy any of sixty-four spaces. This is the system's variety. To increase the complexity of the system let us add another distinguishable chessman (perhaps a different color or type of piece). One piece may occupy any of sixty-four spaces and the other piece may occupy any of the remaining sixty-three. The system has the variety of value of $64 \times 63 = 4{,}032$ possible states. Add another distinguishable piece and the variety increases to $64 \times 63 \times 62 = 249{,}984$ or almost a quarter million possible states.[36] Variety depends on both the number of pieces and the positions available to them.

Variety has exploded on the battlefield since the days of Napoleon. The demands of the modern battlefield disperse soldiers and systems and hide them from view. This increases their possible positions and options. Modern technology not only increases the different types of combat systems, but increases the distance from which those systems can influence an engagement. This variety creates a perplexing control problem for the commander who attempts to manage his forces while trying to dominate the adversary.

In order to control a system, one has to match its variety. In other words, the controller must be able to generate the same variety as the system being controlled. Ashby called this the *law of requisite variety*. This places a huge demand on the controller. With unconstrained variety, control requires the dedication of half of a system's resources to control the other half. If a controller cannot match a system's variety an alternative is to reduce the variety.[37] Possible methods include: limit variety by uniformity; limit variety by imposing control rules; and, limit variety by information.

Table 1 contrasts the variety generated by a set of distinguishable against indistinguishable chessmen (all white pawns, for instance). Uniformity eliminates the need to track sub-systems separately. Examples abound. Imagine the difficulty of tracking tent stakes as serial numbered items. Fortunately, the Army does not do this. If the item is indistinguishable, within a set standard, only the total number matter. Logistics systems often apply this method to interchangeable spare parts, common fuels, and common ammunition.

Table 1 Variety of Positions Chessmen on a Chessboard

# Chesspieces	Distinguishable Chesspieces	Indistinguishable Chesspieces[38]	Control Rule: must have neighbor[39]	Information: known previous location
1	64	64	64	≤ 9
2	4,032	2,016	420	≤ 81
3	249,984	41,664	3,864	≤ 729

The chessman example already includes several implicit rules: each piece must be placed on the chessboard, and only one piece may occupy a give position. Imposing more control rules further reduces the variety. Requiring each piece to occupy a position adjacent to at least one of the others reduces the variety in the two piece system by 90 percent and that of the three piece system by 98 percent (see Table 1). Imposing more rules will further limit the variety. In tactical units, the formation of subunits establishes a required grouping. Kevin Kelly refers to the process of growing organizations from the bottom-up around well designed sub-systems as "chunking."[40] He finds it a successful method of designing an effective organization. Variety confines itself to chunks rather than pieces, and therefore, it is much easier to control.

Information provides the last method of variety reduction. Suppose that you knew the location of a chessman on the board and its ability to move. If the chessman was a king, it could move to any of eight surrounding spaces or remain in its position. This gives it the variety value of nine (providing that it is not constrained by an edge). So even though we have excellent certainty of its state, the position and type of piece, the system still contains variety. If more pieces are added with the ability of any or all the pieces to move, the system variety increases (see Table 1), but the information that we receive keeps this variety limited to orders of magnitude less than the original problem. Indeed, information provides the means to control. Stafford Beer highlights the importance of information in cybernetic systems:

> This is what enables us to handle cybernetic systems: it is information. Information kills variety; and the reduction of variety is one of the main techniques of regulation – not indeed because it simplifies the system to be controlled, but because it makes it more predictable. 'Noise' in the system increases the variety (and therefore the uncertainty) without increasing the information.[41]

To develop the concepts of information and noise further, the concept of *entropy* and its relation to information theory will be addressed.

The second law of thermodynamics states that in any natural spontaneous process the *entropy* of the universe will increase. This implies that heat spontaneously flows from hot sources to cold sinks, but not the reverse. It also implies that two different gasses spontaneously mix in a vessel, but will not spontaneously unmix. At the turn of the century Ludwig Boltzman proposed a relationship between the observed qualities of entropy and the behavior of atoms: $S = k \log W$. Entropy, S, depends on the logarithm of the ways, W, ". . . a system [can] be arranged without an external observer being aware that rearrangements have occurred."[42] In other words, entropy depends on the logarithm of the *variety* of the system. Gasses remain mixed because molecules mix in many possible arrangements, but exist unmixed in only two.

Information in some respects parallels entropy and provides a means for defeating it. Claude Shannon developed a theory of information analogous to Boltzman's statistical mechanics. Brillouin used this theory to argue how the information provided by Maxwell's organizing demon[43] directly counteracts entropy.[44] In other words, information fused into a system can counteract the tendency toward disorder and, indeed, actually create order.

Consider a military example. Two units, Company A and Company B, have merged on a road march down Route Red on the way to a fork that divides into Routes White and Blue. Let the vehicle drivers be raw recruits who have no knowledge as to which route to take at the fork, nor any sense to stay with their units. The second law of thermodynamics suggests that the units will remain mixed as the vehicles proceed on Routes Blue and White beyond the fork. Into this scenario let us introduce Maxwell's demon in the form of an MP manning a traffic control point at the fork. The MP knows that Company A must go down Route White and Company B must go down Route Blue. At the check point he reads the bumper numbers and sends the vehicles down the appropriate routes. The MP defeats disorder by introducing information into the system.

Taking the above analogy still further, we know that trained soldiers driving the vehicles have some knowledge and instructions. They have been trained to recognize other members of their unit and stay together on road marches. If only a few soldiers had understood a route briefing prior to the movement, and could convince their comrades of their correctness at the fork in the road, the companies woul. *self-organize* at the critical moment and proceed on the correct routes. Again, the transmission of meaningful information, such as self recognition, allows organization to appear out of chaos.

Information provides a crucial element of all viable systems. Hermann Haken, in his book Information and Self-Organization, argues that the transmission of meaningful information makes life itself possible:

> In a cell, thousands of metabolic processes may go on at the same time in a well regulated fashion. In animals millions to billions of neurons and muscle cells cooperate to bring about well-coordinated locomotion, heartbeat, breathing or blood flow. Recognition is a highly cooperative process, and so are speech and thought in humans. Quite clearly, all these well-coordinated, coherent processes become possible only through the exchange of information, which must be transmitted, received, processed, transformed into new forms of information, communicated between different parts of the system and at the same time . . . between different hierarchical levels. We are thus led to the conclusion that information is a crucial element of the very existence of life.[45]

Haken could have as easily been discussing the operation of a modern division or corps in the field; communicating meaningful information is what makes the whole system work. One must dispel notions of a monolithic organization sending information up and decisions down to understand how this system operates. Different elements, both horizontal and vertical pass messages that depend on mutual recognition and cooperation. This information exchange allows self-organization to occur at all levels.

The collection and distribution of information is central to the problem of command and control. Information counters uncertainty and limits variety. Creveld sees only two approaches to deal with the lack of information: "One is to increase information processing capacity, the other to design the organization, and indeed the task itself, in such a way as to enable it to operate on the basis of less information."[46] He suggests several approaches: either ". . . increase the size and complexity of the central directing organ; . . . [implement] a drastic simplification of the organization . . ., or [divide] the task into various parts . . ."[47] In his article "Command and Control at the Crossroads," Thomas J. Czerwinski analyzes Creveld's archetypes in what he terms: command-by-direction; command-by-plan; command-by-influence.[48] Like Creveld, Czerwinski criticizes command-by-direction, the central directing method, and command-by-plan, the rigid planning method. He argues that methods to centralize or prioritize uncertainty unnecessarily involves the higher level commander in tactical decisions that are better made at a lower level, and that they ". . . stand in danger of being self-defeating."[49] What Czerwinski terms command-by-influences seeks to distribute uncertainty to lower levels where it can be better managed.[50] The centralization verses decentralization debate reflects a core fear of the use of information technology to counter uncertainty.

Despite the fact that nobody argues that higher echelon commanders should make tactical decisions for companies, the fears of what a brigade, division, or even corps commander might do with such a high resolution of information are very real. However, arguments advanced by Creveld, Czerwinski, and Bolger take a monolithic view of the organization and propose a false dichotomy between centralization and decentralization.

These authors find value in decentralized command and argue that centralization undermines initiative. However, centralization and decentralization are not mutually exclusive concepts in cybernetic systems.

First, centralized information serves the success of the lower tactical commander if the higher echelon commander applies his or her unique influence to the matter. Stafford Beer compares this dilemma to the higher manager trying to make his team win a sports match:

> Suppose that as a higher manager you have the responsibility to ensure that team A wins in a game which is already being played between team A and team B, where the scoring is already even. You could dress yourself in the appropriate regalia and charge onto the field of play. The players would recognize you. Your side might defer to your tactics . . . while the other side would do their level best to put you out of action. This is not the way to behave at all. If you had authority over this situation, the clever action would be to change the rules of the game so that your side must win it. You belong to a higher order system than the game system; your information is better; you command the facilities for variety generation.[51]

The division or corps commander has the ability to "change to rules of the game" by introducing pressure on the enemy elsewhere on the battlefield or by giving the "team captain," the tactical commander in contact, more resources to win. The higher echelon commander has more resources to introduce variety in the enemy's environment. However, cases like the helicopter syndrome in Vietnam, prove the all to common case of the higher echelon commander playing company commander.[52] Beer argues that centralized information can and should produce better outcomes.

A second reason to reject the false dichotomy between centralized and decentralized control is that the ultimate cybernetic systems, living organisms, do not behave that way. Beer rejects the dichotomy on biological grounds:

> You need take only a quick look at the cybernetic facts to see the fallacy. If I personally were centralized, then - concentrating as I am on what I am saying - I should forget to tell my heart to beat, and drop dead at your feet. . . . On the other hand, if I were fully decentralized, try as I might to concentrate on this talk, the need of my body for fluid . . . would send me rushing from the room to recharge this empty glass, regardless of the talk.[53]

Finally, a the centralized/decentralized dichotomy does not explain self-organization. A decentralized decision either lacks coordination, or requires consensus. Either approach leads to mediocrity. The cross-relations established by large distributed networks grow exponentially with the size of the organization. Agreement across such a large distributed organization becomes next to impossible. Instead, Beer sees authority building around information:

> The trick there is that *information* constitutes authority. It is not that authority resides in a particular office or upholstered chair: it is not that authority is divided into equal parts throughout a democracy. It is that the system can recognize the appropriate focus of knowledge for a given decision, and agrees to abide by the decision there made.[54]

The centralized/decentralized dichotomy comes from the paradigm for a monolithic organization, but Beer's concept of authority developing around information clearly does not. He argues that viable systems are both centralized and decentralized at the same time. He sets forth new criteria for approaches to decision: fast-acting, self-regulating, and self-organizing.[55]

A commander must control the battlefield in order to win. The management of variety through fast-acting, self-regulating, and self-organizing control loops becomes his means of success. The commander controls variety in his environment by distributing decision making that organizes on the authority of information. Specifically, he sets the decision rules that allocate resources where they can be best used when they are needed. He defeats the enemy by introducing more variety in the enemy's environment than can be handled, and by limiting the enemy's ability to produce variety. Increasing variety in the enemy's environment is a form of command and control warfare. Stealth, deception, and simultaneous attacks on multiple avenues using combined arms and joint forces overwhelm the advisory's ability to match the variety of his environment to gain control. Speed, provided by initiative and fast decisions, magnifies these effects. The adversary's ability to introduce variety into the friendly environment is his freedom of action. The commander limits this by restricting the enemy's ability to maneuver, neutralizing entire combat systems, and predicting what the enemy will do before he does it. All of this serves to gain control of the battlefield. This is information dominance.

IV. Decision Loops

Decision loops tie information to action. As with all cybernetic systems, the feedback of information drives action. The decision process invokes programmed rules or heuristics that are designed to apply to the incoming information. Israel Mayk and Izhak Rubin analyzed an array of military decision paradigms (loops) to find the common characteristics:

> The common denominator of all C^3 paradigms is decision theoretic in nature. Namely for each system level *observation* there is a corresponding system level *action*. Just as we must be able to read before we write, we must be able to observe before we can act. A system-level decision-rule is invoked to select a system-level action for a given system-level observation.[56]

This implies a twofold design problem. First, the designer must determine the decision rule (what decision will be made), based on what information, and by whom. Second, he must design the information flow by deciding how, where, and when the information is collected and disseminated.

Therefore its question becomes, what criteria constitutes a good design. Cybernetic decision processes should be fast-acting, self-regulating, self-organizing. Fast-acting loops require distributed decision authority. Authority must reside where information resides and the means exists for action. Self-regulating implies not only the means to achieve the desired end-state, but also homeostasis, that is, decision rules and information flows that adapt to changing circumstances to ensure stability. Self-organizing systems build around the authority of information. The system allocates the means to the point in the system with the information to use it. Decision rules quickly establish these structures based on the dynamics of the battle. Finally, an effective military decision loop considers the enemy as an active opponent with its own decision process. Dr. Harry van Trees, former U.S. Air Force chief scientist writes:

> At the decision making level, we must remember that we are dealing with an intelligent adversary and consider his possible reactions to our strategies. We also must remember that we are fighting an information war and that disrupting, confusing, or destroying his C^3 is a key element in an overall strategy.[57]

Well designed decision loops fight the information war. The most well known example that attacks the enemy's decision process is the OODA loop.

Colonel John Boyd developed his famous decision loop based on his studies of air-to-air combat in the Korea War. He explained the success of American pilots, in part, based on the superior observation afforded by the bubble canopy of their F-86's. In dogfights, the F-86 pilots could observe and react quicker than their communist opponents in their faster MIG-15's. From his extension of his analysis to land combat, Boyd developed a theory for decision in combat:

> Conflict can be seen as time-competitive observation-orientated-decision-action cycles. Each party to a conflict begins by observing. He observes himself, his physical surroundings and his enemy. On the basis of his observation, he orients, that is to say, he makes a mental image or "snapshot" of his situation. On the basis of this orientation, he makes a decision. He put the decision to effect, i.e., he acts. Then because he assumes his action has changed the situation, he observes again, and starts the process anew.[58]

This is the OODA loop (observe. orient, decide, act), or the Boyd cycle (Figure 3). The fundamental idea that this cycle expresses is the connection between information and action.

William Lind, a vocal proponent of maneuver warfare theory, explained and justified much of his theories in terms of the OODA loop. He uses it as a device to emphasize the need for rapidity of action by the advantage gained from completing the OODA loop faster. He contends that by doing so, the enemy's decision process is defeated:

> By the time the slower side acts, the faster side is doing something different from what he observed, and his action is inappropriate. With each cycle, the slower party's action is inappropriate by a larger time margin. Even though he desperately strives to do something that will work, each action is less useful than its predecessor; he falls farther and farther behind. Ultimately, he ceases to be effective.[59]

In other words, to win we must "get inside the enemy's decision loop." Unfortunately, this phase has been reduced to a cliché; often repeated, but without any rigorous meaning or method to accomplish it.

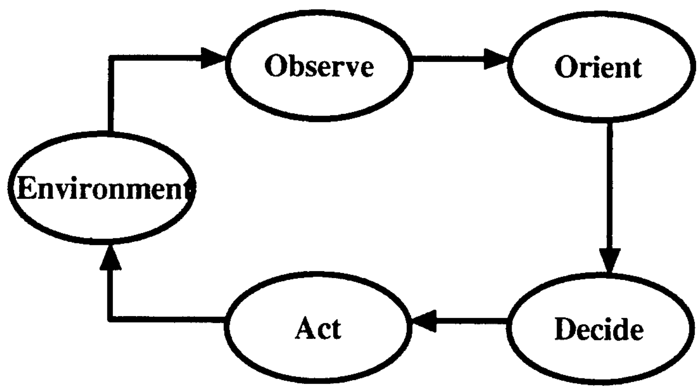

Figure 3. OODA Loop[60]

Lind suggests three criteria to beat the enemy's OODA loop: decentralized control, acceptance of confusion and disorder, and avoidance of patterns and formulas in tactics.[61] He sees decentralized control as the only means to allow for fast decisions. To accept this requires the acceptance of the resulting disorder on the battlefield. Mission-type orders or intent provides the thread of control. The rejection of formulas and patterns prevents the enemy from predicting your next move. Lind defines unit battle drill separately as a technique that should be rehearsed as the building blocks for tactics.

The OODA loop, however, is an inadequate model of command and control. The Boyd cycle, especially Lind's interpretation, takes a limited view of land warfare. Boyd takes the decentralized view of control almost to the level of single combat. Kenneth Allard writes:

> Like the fighter pilot he once was, Boyd clearly envisions combat as a dogfight in which victory depends upon lightning speed, instinctive reflexes, and most of all, positional advantage. Or as Chuck Yeager might have put it, "Get on the other guy's tail and hammer him!"[62]

Lind supports this view of a company or battalion in a duel with its enemy counterpart. For instance, he advocates the allocation of artillery, vertical take-off jets, and attack helicopters to infantry companies for the sake of fire support responsiveness.[63] While a few rare situations may justify such an allocation, it ties the mobility and reach of these scarce assets to the small piece of terrain influenced by an infantry company. This is where the Boyd loop falls short. From his model, the intent from higher echelons provides the sole thread for collective action. Coordination slows the decision cycle, denies victory, and risks defeat. The Boyd cycle, as applied by maneuver warfare theory, seeks to disperse authority evenly across a decentralized array of companies and battalions.

However, Boyd and Lind successfully capture a natural decision model and rely heavily on it for maneuver warfare theory. They choose to emphasize this process over a dependence on new technology. Allard continues:

> Rather than relying on a wealth of electronic communications, leaders control through the use of *Auftragstaktik* (literally, 'mission-type orders'): previous conditioning and a specified but general objective are the primary means used to govern the actions of subordinates. Accordingly, Boyd's 'organic design for command and control' relies heavily on 'implicit orientation' rather than 'explicit internal arrangements' - that is, on general leadership and direction rather than micromanagement aided

by high-technology electronics.[64]

Decoupling the decision process from technology focuses the process on human decision. Herein lies the utility of this approach. But rather than accepting their technology aversion, we should apply technology to enhance these natural decision processes.

Dr. Gary Klein, a former U.S. Air Force research psychologist, studied decision making in fire-fighting organizations in order to explore alternate decision paradigms. Decision makers in these organizations face many of the same challenges as military decision makers. These decision makers command robust (variety rich) organizations and in the course of operations make numerous time-constrained decisions that involve life and death. Klein observes that functional decisions, decisions related to putting out fires, do not involve the simultaneous consideration of alternatives (rational decision process). Instead, decision makers followed, what Klein terms, a recognition-primed decision (RPD) model. In its simplest form, the fire chief pairs the operational goals with his expectancies to sort critical cues from the information his staff feeds him. From this, he generates a typical reaction based on heuristics and implements the action. This process mirrors the Boyd OODA loop. For a more deliberative decision, the chief works through sequential options by generating, evaluating, then modifying or rejecting them (Figure 4). He either implements the option, or, if rejected, generates a new option to start the process again.[65]

The RPD uses the goals of the operation as well as the experience of the decision maker to regulate the response generated from information and cues (feedback). Feedback travels through the pre-processor of the decision maker's experience, where he looks for critical cues. However, RPD reliance on pattern recognition to invoke a typical

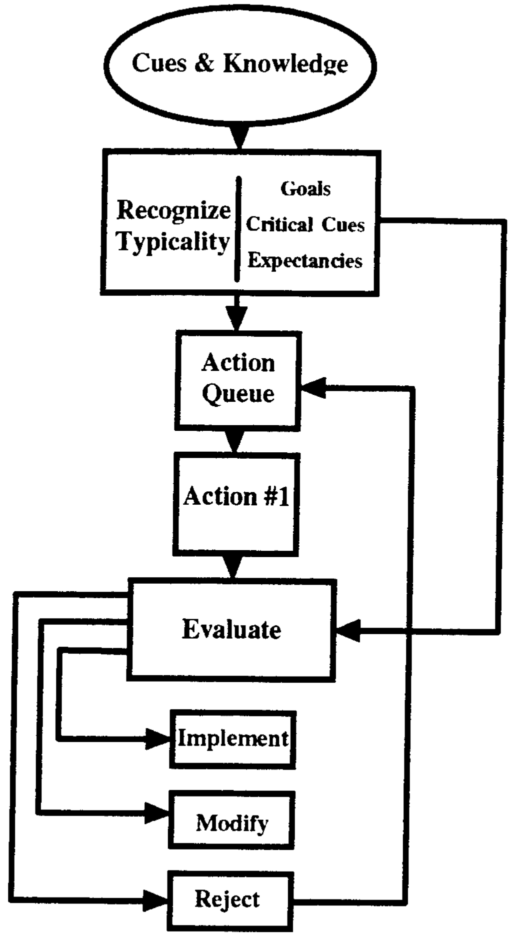

Figure 4. Recognition-Primed Decision Model[66]

response is somewhat dangerous in combat. Fires are unpredictable and dangerous, but this is not the same as an active, thinking enemy.[67] A typical response invoked on a recognized pattern has the same probability of working on future fires as present ones. Lind would argue that a typical response is predictable and would eventually fail under the OODA framework.

Both OODA and RPD are manifestations of natural decision methods. They show that decision makers employ a combination of mental images and visual queues use to arrive at a decision and implement it. Both fall short as models for command and control structures, because neither shows how decision processes ties the organization together.

Dr. Joel S. Lawson, a U.S. Navy C^3I expert, developed his model from a different point of view. He built a model of a command structure for a fleet. The four step decision loop at the center of his concept, *sense-compare-decide-act*, connects to the surrounding environment through the sense and act steps. It also connects with the higher organization through the compare step. This step compares the state of the environment with a desired state that is acted upon by the higher echelons. This results in a modular, rather than a completely integrated system (Figure 5). Allard explains how this modularity fits in with Lawson's concept of command and control:

> Lawson can be defended also on the grounds that his basic model fits well with his larger concept of command and control. This view treats command and control, or simply 'command control,' as a *process* in which different components have different roles while operating as part of a larger system. Lawson asserts that to talk about a completely integrated C3I system is ridiculous. Its various parts must be pretty much self-contained and perform definable and separable functions so that we can change one 'module' without affecting all the others. It then follows that the purpose of the command and control process is either maintain or change the equilibrium state of the environment, as determined by the higher authority.[68]

Lawson takes a rather simplistic view of modularity. One might expect this since he uses the Navy as his model system, which he admits is the "... most technically sophisticated yet least demanding [command and control] problem faced by any of the services."[69]

Compared to Boyd, Lawson takes a more general view of command and control. Lawson uses the environment as his control objective and builds a modular, nested organization as the control structure. Boyd targets the enemy's decision process as the control objective and provides no organizational structure. While the enemy's decision process is extremely important, it is not always the major objective. Further, Boyd's model achieves success in a flurry of action that paralyzes the enemy's command and control. The Lawson model does not prescribe this, but leaves it as an option.

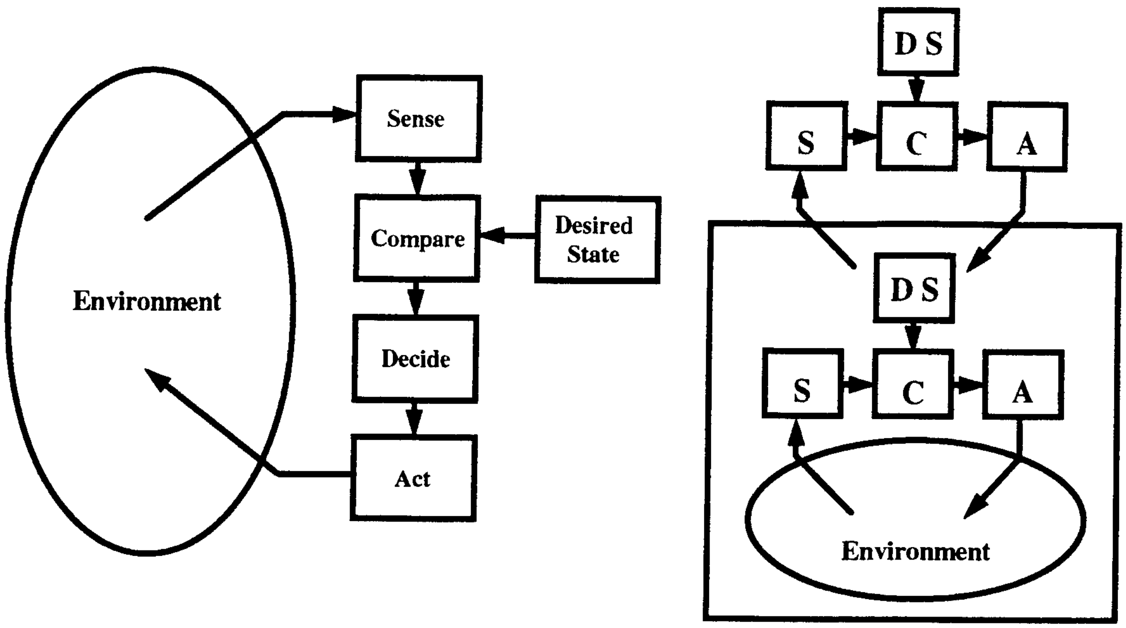

Figure 5. Four Step Lawson Loop and Three Step Nested Loops[70]

Army doctrine addresses the *decision and execution cycle* in FM 100-6, Information Operations. This is a four step process. First the commander strives to gain *battlefield visualization* by acquiring information on both the friendly and enemy forces through all available sources. Second, he develops an initial concept in the *planning* phase based on the received mission. Third, he makes a *decision* among courses of action. Finally, he implements the plan in the *execution* phase, monitors the execution, and collects information for future actions. The unit continually plans, executes, and processes information in order to maintain a high tempo of operations.[71]

The decision and execution cycle is a planning rather than a decision cycle. The staff gathers information to support the planning process and decrease the commander's uncertainty. Planning culminates in a rational decision between developed alternatives. The commander uses information sources and personal observation to monitor the execution of the plan. The planning cycle can be used to design processes, and as an adaptive structure to continually update decision rules of a decision cycle. A decision cycle uses information to drive action. The mission and decision rules act as a regulator to keep the unit moving toward the desired end-state.

Several more decision loops are described by Army doctrine. One of these is the *decide, detect, deliver, and assess* (D3A) loop. D3A integrates intelligence collection assets with weapon systems into the so called sensor-shooter link. In the decide phase the commander sets priorities for collection, and establishes the method and priority for attacking targets through all phases of the plan. The products that result from this phase include the high priority target list (HPTL), attack guidance matrix (AGM), target selection standards (TSS), and intelligence collection plan. The detection phase executes the collection plan to detect and track targets on the HPTL. If the target qualifies by the TSS, the situation requires various technical and tactical decisions such as choice of attack system, time of attack, choice of alternate munitions, and actions on targets of opportunity. After target engagement in the deliver phase, collection assets determine battle damage in accordance with the collection plan, or effects are assessed based on munitions effectiveness. The target is reattacked if necessary. The commander uses results from the effectiveness of attack in the next decide phase.[72]

To help envision this decision loop, consider D3A at the brigade task force level. This process encompasses two types of decisions: planning decisions and execution decisions. Planning decisions establish the framework for the execution decisions. They define the decision rules and allocate the resources. The brigade commander centralizes these decisions. Execution decisions, on the other hand, are distributed about the brigade task force and occur at fire direction centers, fire support elements, forward air controllers, etc. These are the tactical and technical decisions made after the target is detected. In essence, the D3A process has two layered feedback loops: one for planning decisions, and the other for execution decisions. There are other multilayer approaches. Mayk and Rubin proposed a seven layer decision model[73] and Holmes and Morgan proposed a six layered model.[74] In these models, higher layers deal with processes and future events. The lower layers manage the physical and present.

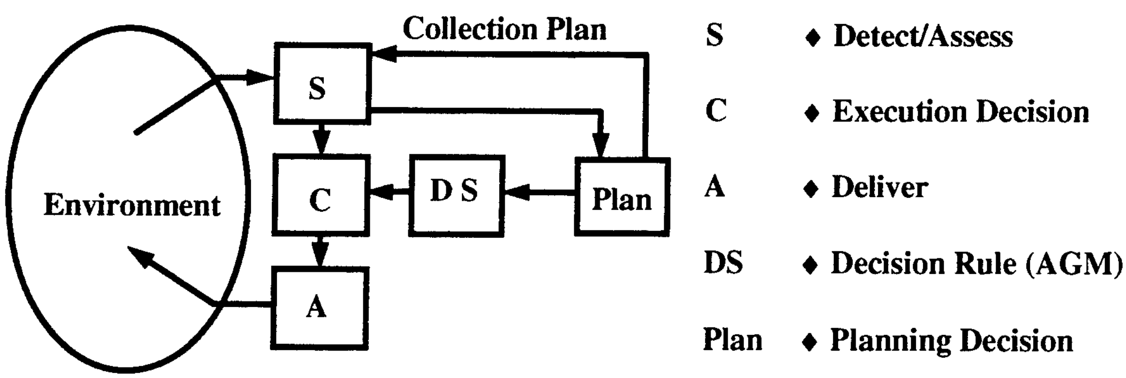

Figure 6. Two Loop D3A (Lawson) Model

The two layer decision structure of the D3A cycle can be applied to the Lawson model. Figure 6 shows this process in a three step Lawson loop with a self-adapting regulator. The sense step includes both the detect and assess step because these functions use collection assets addressed in the collection plan. The compare step is the execution decision based on the decision rules established in the HPTL, AGM, and TSS. The action step corresponds to the delivery step. The planning step sits on a second layer loop. The sense step assesses changes in the environment and feeds this into planning.

The updated plan can change the collection plan and the decision rules. The second loop acts as a homeostat that self-adapts the sensing functions as well as the decision rules. With the second loop, the system achieves Ashby's ultrastability. The distributed nature of the execution decision makes the system fast acting. Delivering fires on a target within the decision rules do not require command level decisions.

The brigade decision loop networks to other echelons through multiple links. For instance, information gained in the sense step feeds into higher echelons. Conversely, execution decisions for brigade assets may be linked to information gathered by division collection assets. Execution decisions at the brigade level can link directly to division delivery systems based on the application of a decision rule, and division execution decisions can directly task brigade assets. The planning levels link through mission orders and the target nomination process. The application of information technology will increase the speed, number, and reach of these links.

Suppose that echelons were linked only through the planning steps, that is, only mission-type orders. No facility would exist to quickly organize the entire system so it could mass weapons effects when needed. Instead, the multiple links create a network that allows self-organization. The fire support system can move quickly from decentralized to highly centralized if correct decision rules are met. For instance, if a forward observer detects a large high priority target the system will organize, if necessary, to direct the assets of several artillery battalions operating, temporarily, on the observer's authority. The supporting units may have been assembled from higher echelons or neighboring brigades that were in position to fire. The system organizes on the authority of information. It rapidly moves from decentralized to centralized and back again as the situation mandates.

Effective decision loops exploit information not only by fast action, but by the ability to self-regulate or adapt to changing circumstances and the ability to self-organize to mass combat power at the critical point and time. Self-organization allocates resources to act together under the authority of the best information in the system. Boyd and Lind argued that commanders must push authority to the lowest level to ensure fast action. Klein's RPD model supports this rapidity by quickly pairing a typical response with critical cues, analyzing and modifying the response, then implementing it. Planning can provide the commander with an array of suitable responses. The method of searching for critical cues allows the commander to change his plan based on the enemy's situation rather than attempting to fight a plan no longer suitable to the situation.

The process of finding those critical cues, however, becomes the difficult step. The commander is limited in his capacity to sort through enough information to find his cues, and limited in the number of responses he can implement. The staff must know the commander's critical informational requirements, but more important, they must understand his mental image of the battle and how information relates to that image. Kahan et. al. reinforce this point in their study of warfighter exercises:

> The commander seeks a dynamic *image* of the battlefield that will lead him to understand what *action* needs to be taken. This image, which is the commander's mental model of the battlefield and its contextual surroundings, includes military, political, and psychological considerations. . . . The *meaning* of any information gained by the commander is driven by the image that frames it, and the value of that information is determined by the manner in which it fits into the image.[75]

This image also defines the bounds of the commander's capacity to see the battlefield and implement correct responses.

Because of the complexity of the battlefield, a brigade, division, or corps commander operates at layers above the execution level. His job is to set the decision rules that facilitate rapid execution and self-organization. This is not to say that the commander cannot hold critical execution decisions, or personally inspect lower echelons. Nevertheless, the outer layer serves to adapt the organization, set the objectives, and update decision rules that facilitate self-organization. The commander must design his organization to rapidly move from decentralized to centralized control and organize around the focus of information.

V. CONCLUSIONS

Human capability sets the bounds for the rational paradigm: the amount of information a decision maker must absorb and the number of decisions required to directly control larger tactical units (brigades through corps) are clearly limiting. The complexity of the modern battlefield and the explosion of information put this strict approach beyond reach. Staff structures, efficient information processors that they are, can grow in size and employ more technological tools, but this will not change the capacity of the decision maker to handle the information without a different approach to decisions.

The cybernetic decision model connects the flow of information directly to action and exploits its time value. Control becomes the central theme; not by trying to bend a corps exactly to the commander's will (and stifling initiative in the process), but controlling the battlefield and organizing the corps to achieve it. By applying Ashby's law of requisite variety, control becomes an exercise in the management of variety. Building the organization around well defined working sub-units or "chunks" reduces a great deal of variety. The fusion of information into the system also reduces its variety. Careful design of decision rules combined with information sets the conditions for collective action. It provides the means for self-organization. Centralized action does not always result from high level intervention; rather, it results form high level design and collective action resulting from the authority of information.

Present military staffs do not operate solely within a rational decision paradigm; the structure of the sensor-shooter link provides an example of alternate processes. Applying the Lawson loop to the D3A loop reveals an organizational process by layering it into two loops: a planning loop and an execution loop. The commander influences the process in the planning loop. Planning sets the decision rule that regulates the execution loop. Information drives the execution loop and feeds back into the planning loop. The planning loop provides the self-regulation or the homeostasis. Layering is a functional separation. Executors include shooters, observers, and sensors that may exist in a number of command echelons.

Analysis of the D3A process shows how layering and networking facilitate collective action. There is functional connectivity as well as a chain-of-command. The networking of information from sensors connects command echelons and allows action based on collection at another level. Action can concentrate at the point with the best information corresponding to a decision rule. Rules established at higher layers allow multiple assets to act in concert with a sergeant with the best information in a forward position. Applying more information technology will increase the spread and decentralization of these networks.[76]

Layering and networks present a number of challenges to future leaders. Collective actions built around information place greater demands on junior leaders. Lieutenants, sergeants, and even specialists must be prepared to act as the focus for multiple assets assembled for their support. Likewise, senior leaders must resist the temptation to directly command lower actions. They reside in the outer layers of decision. This does not relieve them of the responsibility to provide moral leadership and to personally inspect the function of the lower decision layers. Technology may temp commanders to act as latter-day Napoleons, but the variety of the modern battlefield will deny them success.

ENDNOTES

1. David G. Chandler, The Campaigns of Napoleon (New York: MacMillan Publishing Co., Inc., 1966), 425.

2. Ibid., 418-419.

3. Christopher Bellamy, The Evolution of Modern Land Warfare: Theory and Practice (New York: Routledge, 1990), 45-46.

4. James J. Schneider, "The Theory of the Empty Battlefield," JRUSI (September 1987), 37-44.

5. Variety is a function of the number of separate moving parts and the possible arrangements of the parts. Tactical structure, doctrine, terrain, and other factors constrain these arrangements. Modern armies have more types of combat systems, more flexible tactical arrangements, and more tactical mobility than those of Napoleon. These factors increase variety. Variety will be discussed further in chapter 3.

6. James R. Beniger, The Control Revolution (Cambridge, MA: Harvard University Press, 1986), 219.

7. Ibid., 13.

8. Martin van Creveld, Command in War, (Cambridge, MA: Harvard University Press, 1985), 149.

9. Ibid., 267.

10. J. F. C. Fuller, Generalship: Its Diseases and Their Cure (Harrisburg, PA: Military Service Publishing Company, 1936), 66.

11. Daniel P. Bolger, "Command or Control?" Military Review (July 1990), 75.

12. TRADOC PAM 525-5, Force XXI Operations (Ft. Monroe, VA: CACDA, August 1, 1994), 3-4.

13. Coup d'oeil (*French*) literally means stroke of the eye or a quick glance. Frederick the Great used the term to describe the quality of being able to look at the terrain or military situation and instantly determine the appropriate action. The quip, *coup d'oeil goggles,* pokes fun at the concept of this quality of genius being reduced to a set of virtual reality goggles. The quip merits discussion since it forces thought as to the limits of information technology, if such limits exists. I am attributing this quip to LTC Scalard who used it in a seminar he lead at the Command and General Staff College, Ft. Leavenworth, March 1996.

14. TRADOC Pam 525-5, 3-4.

15. John D. Steinbrunner, The Cybernetic Theory of Decision, new Dimensions of Political Analysis (Princeton, NJ: Princeton University Press, 1974), 8.

16. Ibid., 56.

17. FM 101-5, Staff Organization and Operations (Final Draft) (Ft. Leavenworth, KS: CACDA, August 1996), 5-5.

18. Steinbrunner, Cybernetic Theroy of Decsion, 26.

19. Ibid., 33.

20. Ibid., 29.

21. M. Mitchell Waldrop, Complexity: the Emerging Science at the Edge of Order and Chaos (New York: Touchstone, 1992), 150.

22. Kevin J. Dooley, "A Complex Adaptive Systems Model of Organizational Change," Nonlinear Dynamics, Psychology, and LifeSciences (Fall 1996).

23. James P. Kahan, D. Robert Worley, and Cathleen Stasz, Understanding Commanders' Information Needs (Santa Monica, CA: RAND Corporation, 1989), viii.

24. Ibid., 3.

25. Kenneth C. Allard, Command, Control, and the Common Defense (New Haven, CT: Yale University Press, 1990), 164.

26. Stafford Beer, Platform for Change (New York: John Wiley and Sons, 1975), 25-30.

27. Ibid, 30.

28. James P. Kahn, et. al., Understanding Commanders' Informational Needs, 35. The authors observed an evening staff upadate to the division commander. Information presented by the G2 and G3 significantly changed the commander's perception of the battle to the point where he issued new guidance. Synthesis through cross coordination should occur before the staff update.

29. Kevin Kelly, Out of Control: the New Biology of Machines, Social Systems and the Economic World (New York: Addison-Wesley, 1995), 119-121.

30. John W. Foss, "Command," Military Review (May 1990), 4.

31. Beniger, The Control Revolution, 7.

32. Bernard Friedland, Control System Design: An Introduction to State-Space Methods (New York: McGraw-Hill, Inc., 1986), 2. Friedland uses an amplifer instead of a regulator in this introductory chapter. The regulator is a more general concept which he applies later in his book.

33. W. Ross Ashby, Design for a Brain (New York: John Wiley and Sons, 1952), 90-91.

34. Ibid., 130-131.

35. Allard, Command, Control, and the Common Defense, 154-155.

36. Donald A. McQuarrie, Statistical Mechanics (New York: Harper Collins Publishers, 1976) 22. The possible states for M distinguishable pieces distributed among N spaces with single occupancy is given by the permutations.

37. Beer, Platform for Change, 110-111.

38. Donald A. McQuarrie, Statistical Mechanics, 22. Indistinguishable objects do not generate variety with respect to the order in the space occupied. Combinations, rather than permutations determine the variety.

39. In a 2 piece system, the second piece may occupy any of 8 spaces surrounding the first piece unless the first piece occupies an edge or a corner. In this case, there are 5 spaces for the former and 3 spaces for the latter condition. For a 3 piece system, the third piece may occupy any of 10 spaces if the second piece is horizontally or vertically situated from the first piece or 12 spaces if the second piece is on the diagonal. This only applies if the first piece occupies on of the 16 center spaces. If the first piece occupies an edge, near-edge, corner, or near-corner, the impossible combinations (piece off the board) must be eliminated.

40. Kelly, Out of Control, 469.

41. Stafford Beer, Cybernetics and Management (New York: John Wiley and Sons, 1959), 43.

42. P. W. Atkins, The Second Law (New York: Scientific American Books, Inc., 1984), 66.

43. James Clerk Maxwell's demon seems overthrow the second law of thermodynamics. His demon sits at a massless and frictionless gate between two closed vessels of gas. As the demon observes a fast moving molecule moving from vessel 1 toward vessel 2 he

lifts the gate, but keeps it shut for slow moving molecules moving in the same direction. Conversely, he lifts the gate for slow moving molecules moving in the opposite direction, but closes it to the fast moving molecules. Over time the temperature of vessel 1 decreases while the temperature in vessel 2 increases. Since the demon has a massless and frictionless gate, no work has been performed to cause this separation. The demon defeats the second law of thermodynamics! The impossibility of this created a paradox that scientists debated for decades.

44. K. G. Denbeigh, and J. S. Denbeigh, Entropy in Relation to Incomplete Knowledge (Cambridge: Cambridge University Press, 1985), 108-112.

45. Hermann Haken, Information and Self-Organization: A Macroscopic Approach to Complex Systems (Berlin: Springer-Verlag, 1988), 23.

46. Creveld, Command in War, 269.

47. Ibid., 269.

48. Thomas J. Czerwinski, "Command and Control at the Crossroads," Parameters (Autum 1996), 121-122.

49. Creveld, Command in War, 269.

50. Czerwinski, "Command and Control at the Crossroads," 125.

51. Beer, Platform for Change, 112.

52. Creveld, Command in War, 255.

53. Beer, Platform for Change, 291.

54. Ibid., 286.

55. Ibid., 299.

56. Israel Mayk and Izhak Rubin, "Paradigms for Understanding C3 Anyone?" in Science of Command and Control: Coping with Uncertainty (Stuart E. Johnson and Alexander H. Levis, eds., Washington, D.C.: AFCEA International Press, 1988), 49.

57. Harry L. van Trees, "C3 Systems Research: A Decade of Progress," in Science of Command and Control: Part II Coping with Complexity (Stuart E. Johnson and Alexander H. Levis, eds., Fairfax, VA: AFCEA International Press, 1989), 36.

58. William S. Lind, Maneuver Warfare Handbook (Boulder, CO: Westview Press, Inc., 1985), 5.

59. Ibid., 6.

60. Allard, Command, Control, and the Common Defense, 151.

61. Lind, Maneuver Warfare Handbook, 7.

62. Allard, Command, Control, and the Common Defense, 150.

63. Lind, Maneuver Warfare Handbook, 31.

64. Allard, Command, Control, and the Common Defense, 151.

65. Gary A. Klein, "Naturalistic Models of C3 Decision Making," in Science of Command and Control: Coping with Uncertainty (Stuart E. Johnson and Alexander H. Levis, eds., Washington, D.C.: AFCEA International Press, 1988), 88.

66. Ibid., 88.

67. Ibid., 91.

68. Allard, Command, Control, and the Common Defense, 152.

69. Ibid., 154.

70. Ibid., 153.

71. FM 100-6, Information Operations, 4-1 to 4-2.

72. FM 6-20-10, Tactics, Techniques, and Procedures for the Targeting Process (Washington D.C.: Department of the Army, 8 May 1996), 2-1 to 2-16.

73. Mayk and Rubin, "Paradigms for Understanding C3 Anyone?," 55.

74. J. E. Holmes and P. D. Morgan, "On the Specification and Design of Implementable Systems," in Science of Command and Control: Coping with Uncertainty (Stuart E. Johnson and Alexander H. Levis, eds., Washington, D.C.: AFCEA International Press, 1988), 96.

75. Kahan, et. al., Understanding Commanders' Information Needs, vi.

76. TRADOC PAM 525-5, Force XXI Operations, 2-8.

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